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RESEARCH NEEDS IN WATER QUALITY CONSERVATION

by

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I should like to thank the Program Committee for approving the subject of this talk. Such assignments force us to contemplate our position with respect to the adequacy of the tools and techniques of the profession. This is a hard and sometimes thankless task -- but it is an essential function of the Robert A. Taft Sanitary Engineering Center.

In May 1958 we had a similar assignment in preparing for the Conference of Man vs. Environment.* Before the Conference, the SEC was asked to outline important research needs in respect to man's relationship with water. In a very short time, sixteen major projects on water supply and pollution control were described. Each was focused on a significant problem in the broad field of water quality conservation.

Preparing this list was not difficult. The SEC is in an advantageous position for securing such information because of the many requests we receive for assistance on difficult and unusual problems. Although our relatively small resource permits us to respond to only a few of these requests, knowledge of important new problems is literally

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forced on us. This is desirable from our point of view. Not only do we learn of emerging problems, we obtain guidance as to the direction our research should take. I propose to base my discussion largely on the information so obtained.

First, I should like to make a broad and perhaps disagreeable generalization. Because of the inadequate knowledge, scientifically sound management of water quality is hardly possible at present in many river basins. This statement represents the opinion of many of our senior staff and colleagues. Perhaps some of you will not agree. I'm sure you will be interested in an elaboration of this statement.

Proceeding in logical fashion from the origins of waste to ultimate water reuse, our broad areas of ignorance are encompassed by the following questions:

Do we account for all pollution reaching streams?

Having a new waste in hand, can we predict its potential pollutional effects?

Assuming we can determine tolerance levels for this waste, can we really treat it effectively?

In disposal of waste effluents, do we make effective use of the receiving water?

Having disposed of the waste effluent, can we monitor effectively the quality of waters which have received it?

Can we effectively treat polluted water for reuse?

Each of these questions offers its major uncertainties and its consequent challenges to research.

Origin of Wastes

Do we account for all pollution reaching streams?

When we think of pollution, we normally consider sewage and industrial wastes. This is not surprising. One expects an industrial plant to produce an industrial waste just as a community produces sewage. But I believe that few have considered the growing pollutional effect of land drainage, particularly that from agricultural lands. Perhaps even fewer are aware of pollution resulting from chemical poisons deliberately applied to the water course to kill weeds, insect larvae, fish, and other forms of aquatic life. We thus have at least four major avenues through which man-made pollution may reach streams: sewage, industrial wastes, land drainage, and direct chemical applications. Each warrants close study by the sanitary engineer.

1. Let us consider sewage which is assuming new, important characteristics. For example, synthetic organic chemicals are often undetected and unsuspected components of sewage. It is probable that the presence of alkyl benzene sulfonate, the basic ingredient of household synthetic detergent, would be unsuspected if it were not associated with foam. One could speculate on the presence of other substances, equally resistant to treatment and equally persistent in the stream, which give no physical or chemical clues to their identity.
2. It is not necessary to belabor the point that the "traditional" industrial wastes, the dinosaurs of our experience, are still major problems. However, new and perhaps even more troublesome wastes are being encountered. Increasing interest is

being directed to radioactive wastes from uranium ore refining plants and nuclear power reactors, thermal pollution from power plants and industrial cooling operations, and the vast complex of waste substances discharged by the chemical industries. Synthetic organics are a particular problem because of the very rapid growth of the petrochemical industries. Many of these organic compounds resist destruction by the communities of microorganisms on which we depend for organic waste stabilization in the treatment plant and in the stream. They may persist almost indefinitely in the stream, and reach locations of water use many miles below the point of waste discharge. An interesting example is a benzene derivative we followed 1000 miles down the Mississippi River.

3. The increasing use of agricultural poisons, particularly insecticides, is reflected in the appearance of these chemicals in bodies of water receiving farm land drainage. DDT has frequently been recovered from streams, and even from treated water supplies. One of the new chlorinated hydrocarbon insecticides is the most toxic material yet encountered for fish. It has been used in Pennsylvania to destroy rodents in orchards. Like other such substances, it is persistent in water solution and is not easily removed by conventional water treatment processes. As materials of increased potency come on the market, public concern with their impact on water use must inevitably grow.

One aspect of this problem is to determine how to control a waste whose source is general land drainage rather than a specific outfall sewer.

4. The growing use of synthetic organic poisons to destroy nuisance water vegetation, mosquito larvae, and undesirable fish has introduced new water quality control problems. Dickinson, North Dakota, provided us with a typical case. To destroy worthless coarse fish prior to restocking with game fish, it was proposed that a fish poison be applied to the municipal raw water impoundment in use. As one would expect, the health authorities were concerned with the ability of the water treatment plant to prevent this material from reaching the treated water. With the increasing recreational appeal of stored waters, it is clear that problems of this kind will be experienced widely and frequently.

Is our concern with these synthetic organics exaggerated? Of the many thousands of compounds of industrial origin reaching waterways daily, we have information on only a few. However, we can't help being impressed by the low concentrations in which these materials may exert their pollutional effects. For example, I have mentioned a certain chlorinated hydrocarbon insecticide which will kill fish in a concentration of less than 1 ppb. Phenols in concentration of just a few ppb have been implicated in taste and odor problems in drinking water. Alkyl benzene sulfonate has been associated with frothing in concentrations of about 1 ppm. Ignorance of the effects of other compounds does

not certify their harmlessness.

The possibility of toxicity for humans is a dominating concern. However, we know of no case of human illness in which synthetic organic substances in a public water supply have been involved. Yet we cannot escape the fact that as the number and size of plants engaged in synthetic organic chemical manufacture increase, their wastes will increase in flow and complexity. No matter how slowly the concentrations build up in receiving waters, this situation may have ultimate public health implications. Here I should like to emphasize that it is not the acute episode we fear -- this would be readily identified. It is the insidious effects that could be associated with repeated exposure over long periods of time to low concentrations of the waste.

Pollutional Characterization of a New Waste

> Having a new waste in hand, can we predict its potential pollutional effects?

Can we confidently predict the effect of the waste on the dissolved oxygen of the stream, its toxic effect on fish and other aquatic life, its tainting effect on fish flesh, its possible damage to water treatment processes, its effect on water palatability, and its harmful effect on persons who drink that water?

I think you will agree that few agencies are presently equipped to do more than estimate the waste's probable effect on the dissolved oxygen of the stream, and to determine, within rough limits, its toxic effect on fish in the receiving water.

Several years ago the Center undertook to evaluate its ability to make such predictions. We selected a group of six organic cyanides as

the wastes of challenge. Chemists, engineers, biologists, and toxicologists were assigned to determine the pollutional character of these compounds. They were instructed to exercise ingenuity wherever standard methods and equipment could not be used. Improvisation was necessary. For example, it was found that conventional organic analysis could not detect nor measure the low concentrations of compounds found to be significant. Quantitative analysis based on fish bioassay solved this particular problem.

Our experience indicates that a well-equipped and well-staffed laboratory can obtain the information needed to predict with confidence a new waste's probable impact on certain important downstream water uses. However, it is an expensive, time-consuming project -- not one to be undertaken as a routine task. The toxicological phase of the study is perhaps its most perplexing aspect. The specialized services and cost necessary for determining the effect of repeated exposure to low concentrations of the waste for long periods of time would inevitably place this job out of reach of most public agencies. Equally discouraging, perhaps, is the probability that the toxicological study may take as long as two years.

Waste Treatment

> Assuming we can determine tolerance levels for this waste, can we really treat it effectively?

Many yardsticks of waste strength and character are in use: Biochemical Oxygen Demand (BOD) is unquestionably the most common. With the best treatment processes available, a BOD reduction of approximately 95% may be obtained. A reduction in BOD does not mean that the objectionable

mineral salts -- nitrates and phosphates -- have been removed. Just the opposite effect is produced in sewage stabilization by secondary treatment. Likewise, the soluble inorganic constituents of wastes are not removed by conventional secondary waste treatment processes. And it has already been noted that many persistent organics discharged in sewage and in chemical industry wastes do not have a BOD. They are either non-oxidizable or they exert their oxygen demand so slowly as to be considered non-oxidizable. Obviously, a reduction in a waste's BOD gives no assurance that such compounds have been removed or destroyed.

The possibility that so-called complete treatment of wastes may not always be sufficient, was pointed out by G. E. McCallum, Chief, Division of Water Supply and Pollution Control, Public Health Service, at the 1959 Purdue Industrial Wastes Conference. A new interest has been stimulated in the future's need for tertiary treatment processes and, beyond that, for ultracleansing of wastes. You may be interested in a few of the investigations under consideration at the Center.

1. Fundamental studies on microbial enzyme systems important in waste treatment. The potential of biological communities for breaking down organic compounds should be fully realized. This naturalistic treatment must, in our opinion, be exploited to the maximum because it costs less than other methods, and because it is a common sense preliminary to any necessary treatment of organic substances by non-biological methods. Research may yield valuable information on how to break down certain kinds of chemical structures now invulnerable to microbial attack, and how to stimulate development of more adaptable microbial enzyme systems.

2. Fundamental studies on particle separation by filtration. The ultimate potential of filters for particle removal should be established. The relationship of filter design to the size of particles to be removed has not hitherto been adequately investigated. Because of the obvious usefulness of filters at points of waste production, and their very wide employment at points of water use, we should know the ultimate value of this unit process. As part of this project, methods could be explored for producing chemical flocs of controlled size, density, and toughness. Such flocs deposited on filters of various kinds will permit the realization of maximum filter potential.
3. Application of adsorption principle to waste treatment. Effective treatment of complex organic wastes may require, in many cases, the intelligent use of the principle of adsorption. For a number of years, the Center has studied intensively the adsorption of soluble organics from sewage and industrial waste streams and receiving waters. Many materials have been evaluated for their adsorption properties, with special attention directed to activated carbon which has been found, so far, to be the adsorbant of choice. In the summer of 1958, a special evaluation was made of the factors influencing adsorption of organic contaminants. The problem of regeneration of adsorbants is of paramount importance.
4. Destruction of organics by strong chemical oxidants. The feasibility of destroying the organic content of wastes by strong chemical oxidants such as ozone and hydrogen peroxide should

be investigated. In this way, complex organic compounds may be converted to relatively simple inorganic structures which might be removed by some appropriate procedure.

Other physical-chemical phenomena may be useful in waste treatment. Advanced methods of electrodialysis, ion exchange, solvent extractions, and evaporation should also offer interesting research opportunities in water cleansing.

The Center's research on advanced waste cleansing is focused on the potential usefulness of basic physical, chemical, and biological principles, rather than on the development of more complicated equipment. Complex gadgetry does not always solve our problems. I believe I can make my point by paraphrasing an incident reported by Reginald Reynolds in his extraordinary book, "Cleanliness and Godliness". The incident involves the installation and use of the first water closet in a famous old barony in feudal Europe. The device was a miracle of complicated pipes, valves, and levers. It was installed with great pomp and ceremony. Naturally, the elderly lord of the barony was the first to put it to use. And, as he proceeded to do so, a selected group of court nobles in full regalia, stood outside the door singing chorales in honor of their lord and the apparatus he was using. But when they were through, the ancient lord could be heard to say in a weak and dispirited voice, "Non possumas" (no luck).

Waste Disposal.

> In disposal of waste effluents, do we make effective use of the receiving water?

Presumably, available knowledge and experience on lateral mixing and dispersion of wastes in streams should permit full use of the stream's dilution ability. However, plumes of waste may often be traced many miles along a water course. Obviously, the full dilution effect is not being used. This often poses stream sampling problems because of variation in waste concentration in a cross-section of a stream. It also raises pertinent questions regarding the adequacy of outfall design techniques.

Many of you have personal knowledge of the relatively poor state of the art of waste disposal into tidal waters. A profound question is, "What is the fate of a particle of waste discharged into a mass of tidal water?". The intelligent use of coastal waters and estuaries for waste disposal was the subject of an International Conference held last month at the University of California in Berkeley. Every one of the 24 coastal and Gulf States is seeking, or will inevitably seek, effective techniques to answer this question. The use of models to supplement field studies is a recent interesting development.

Water Quality Monitoring.

> Having disposed of the waste effluent, can we monitor effectively the quality of waters which have received it?

Until recently, few programs of water quality intelligence could present a realistic picture of changing quality conditions in a stream, and those were usually developed at great expense in special problem

situations. You may recall that in December 1955 the unsatisfactory condition regarding knowledge of the quality of our water impelled the President's Advisory Committee on Water Resources to note that improvement in basic data on water quality was urgent.

The monitoring problem has three important phases: to define what constitutes meaningful data for a given stream; to apply appropriate sampling and analytical procedures; and to fit these data into a scheme of known water uses, waste discharges, and stream flow to permit correct interpretation of data. Obviously, mere collection of data is not helpful if they do not truly reflect changes in water quality.

We are not badly off with respect to detection of certain types of pollution. Recent improvements in sampling and analytical techniques for coliform organisms and enterococci permit us to discern fecal contamination more readily than before. The successful development of equipment for continuous recording of dissolved oxygen represents a significant advance in the monitoring of streams for oxygen demanding wastes. The current emphasis on radioactivity monitoring is providing steadily improved instrumentation for this program. However, many important shortcomings remain.

Perhaps the most significant defect in data collection programs is the inadequacy of procedures for detecting pollution by highly stable organic compounds of industrial origin. A good example is the compound described earlier which could be recovered 1000 miles below its point of introduction into the stream. Its presence was suggested by an unusual peak in the infrared absorption spectrum. Only by using the most advanced techniques of sampling and analysis may we hope to detect such

substances. An additional shortcoming is the failure to take full advantage of stream biota as useful indicators of pollution. Although biologists have repeatedly stressed the sensitivity of aquatic life to water quality changes, our approach remains relatively crude and expensive.

It must be re-emphasized that collection of data is not important if they do not relate to water quality. The time is ripe for close, critical scrutiny of the kind of information now being recorded in water quality basic data programs.

Water Treatment

Can we effectively treat
polluted water for reuse?

The main function of the modern water treatment plant is to remove particles suspended in the water, and to destroy microorganisms that manage to survive flocculation and filtration procedures. Except for removal of hardness, little attempt is made to remove soluble chemicals in drinking water. Where taste and odor are highly objectionable, carbon is usually applied. But carbon is selective in its action, and sometimes it is ineffective. We actually know little about the principle of adsorption as it applies to the use of carbon. Moreover, there is no assurance that harmful substances in solution will signify their presence by producing taste and odor. Here, as in waste treatment, interesting research opportunities exist.

CONCLUSION

My assignment has been to consider major needs of water quality research. I have addressed my remarks to the following questions:

1. Do we account for all pollution reaching streams?
2. Having a new waste in hand, can we predict its potential pollutional effects?
3. Assuming we can determine tolerance levels for this waste, can we really treat it effectively?
4. In disposal of waste effluents, do we make effective use of the receiving water?
5. Having disposed of the waste effluent, can we monitor effectively the quality of waters which have received it?
6. Can we effectively treat polluted water for reuse?

These, I believe, encompass the important areas of concern to agencies responsible for water quality conservation.

Perhaps in stressing areas of ignorance, I have been guilty of painting an unduly gloomy picture of the state of our art. We need not apologize. The success of sanitary engineers is controlling filth in water and, by so doing, eliminating the epidemic diseases associated with filth, is one of the great triumphs of public health.

You will be interested, I am sure, in the respect for the profession recently expressed by Aldous Huxley, the great English writer now residing in the United States. In his essay, "Hyperion to a Satyr", Huxley discusses in deeply learned, but humorous style, man's historical relationship to filth. His essay opens as follows:

"A few months before the outbreak of the Second World War I took a walk with Thomas Mann on a beach some fifteen or twenty miles south-west of Los Angeles. Between the breakers and the highway stretched a broad belt of sand, smooth, gently sloping and (blissful surprise!) void of all life but that of the pelicans and god-wits. Gone was the congestion of Santa Monica and Venice. Hardly a house was to be seen; there were no children, no promenading loin-cloths and brassieres, not a single sun-bather was practising his strange obsessive cult. Miraculously, we were alone. Talking of Shakespeare and the musical glasses, the great man and I strolled ahead. The ladies followed. It was they, more observant than their all too literary spouses, who first remarked the truly astounding phenomenon. "Wait," they called, "wait!" And when they had come up with us, they silently pointed. At our feet, and as far as the eye could reach in all directions, the sand was covered with small whitish objects, like dead caterpillars. Recognition dawned. The dead caterpillars were made of rubber....."

".....how on earth had these objects got here, and why in such orgiastic profusion? Still speculating, we resumed our walk. A moment later our noses gave us the unpleasant answer. Offshore from this noble beach was the out fall through which Los Angeles discharged, raw and untreated, the contents of its sewers."

Fourteen years later, Huxley revisited the area and was struck by an amazing improvement. "A happy consummation -- but one has seen this sort of thing before. The novelty lies, not in the pleasantly commonplace end -- people enjoying themselves -- but in the fantastically ingenious means whereby that end has been brought about."

Gentlemen, we sanitary engineers may take a bow.